Ergonomics and the ACGIH® TLVs®

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Acknowledgments

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ACGIH®

The facts stand on their own.

Interpretations, recommendations and opinions are mine. I speak for none of them.

TLVs® for Ergonomics

Statement on Work-Related Musculoskeletal Disorders

Hand Activity Level

Lifting

Hand-Arm Vibration

Whole Body Vibration

Job Risk Factors

Force

Posture

Frequency / Duration

Exposure (Duration of Day)

Who Says So?

Critical Reviews Supporting Causal Relationship Between Risk Factors and WRMSDs

- NIOSH (1997)
- National Academy of Sciences (1998)
- OSHA (1999)
- Keyserling (2000)

Hand Activity Level

2001

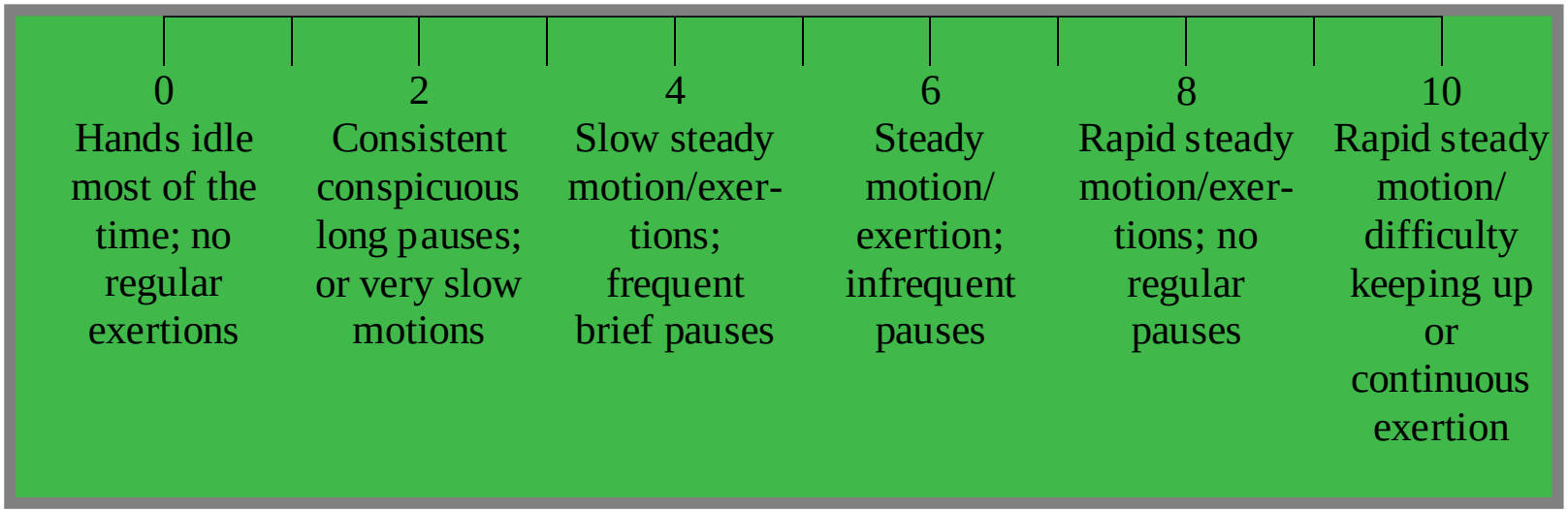
Hand Activity Level

Based on work by Latko at University of Michigan

Desire to develop an observer scale

It is reliable.

HAL Scale


0
Hands idle most of the time; no regular exertions
2
Consistent conspicuous long pauses; or very slow motions
4
Slow steady motion/exer-tions; frequent brief pauses
6
Steady motion/ exertion; infrequent pauses
8
Rapid steady motion/exer-tions; no regular pauses
10
Rapid steady motion/ difficulty keeping up or continuous exertion

Force

Normalized Peak Force (NPF)

- Start with Typical Peak Force (90th %ile)
- Based on Representative Population Strength ($MVC_{5th\ \%ile}$)
- Inclusive of Posture

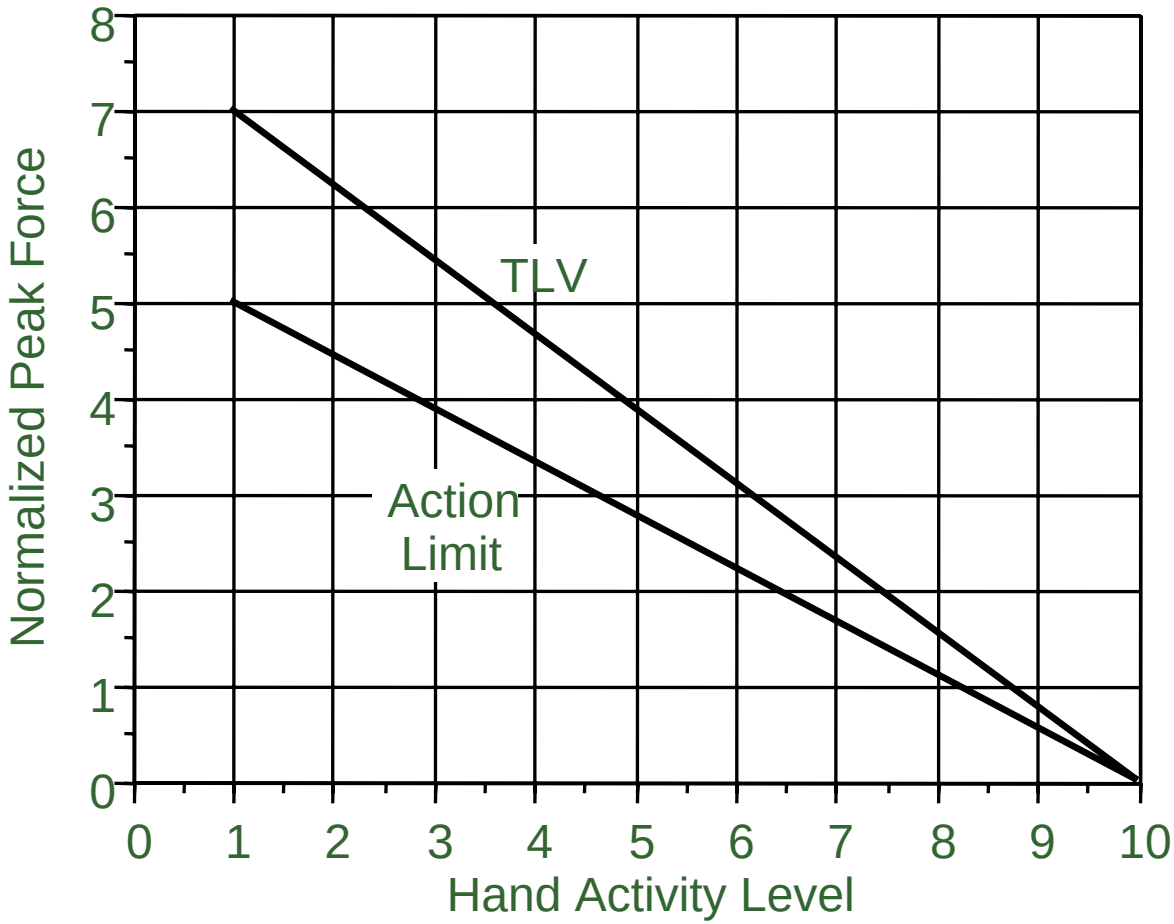
$NPF = 10 x Peak\ Observed\ Force / MVC_{5th}$

Normalized Peak Force

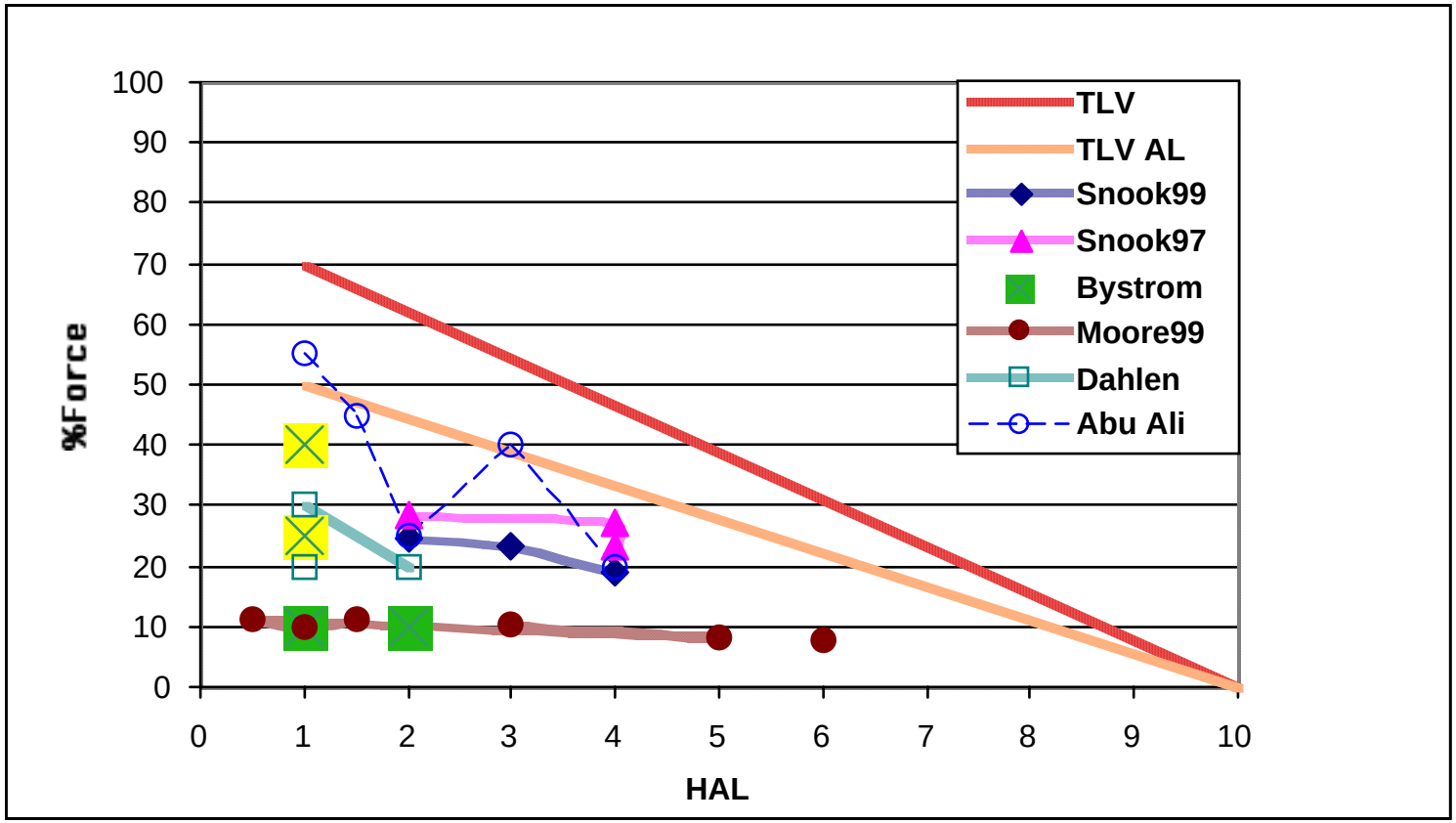
Intended: Measured

Alternatively: Borg Scale

The TLV

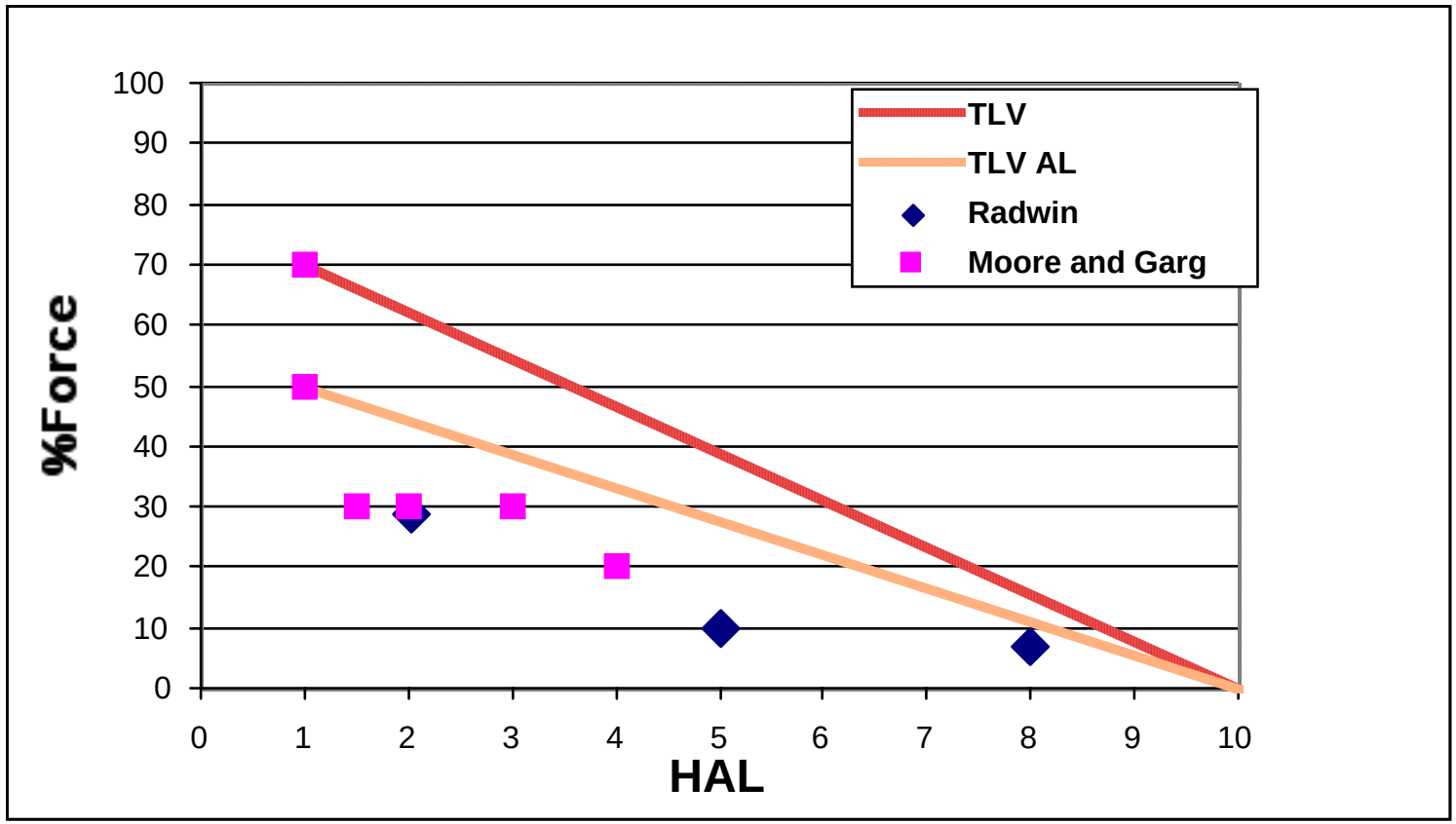

Normalized Peak Force
8
7
6
5
4
3
2
1
0
TLV
Action
Limit
0
1
2
3
4
5
6
7
8
9
10
Hand Activity Level

Compared to Other Studies



Courtesy of Richard Wells, Univ of Waterloo

Compared to Other Methods



Courtesy of Richard Wells, Univ of Waterloo

Lifting

2005

Development

Lifting Scenarios

- 12 Zones
- 3 Frequencies

Start with LI = 2

Adjust Weights with Ohio State (Marras) Model

Compare to Standard Methods

Infrequent

< 2 h/day and <120 lifts/day

Zone	Close	Middle	Far
High	15	7	--
Chest	32	16	9
Low	18	14	7
Floor	14	--	--

Low Frequency Comparison

Vertical Zone:		Horizontal Zone:											
Anatomical Landmarks	Start Height of Lift	Close[1]				Intermediate[2]				Extended[3]			
		TLV[5]	3D[6]	Sn[7]	LI[8]	TLV	3D	Sn	LI	TLV	3D	Sn	LI
From 8 cm below Shoulder Height [Ht] to above Shoulder Ht[4]	Over 132 cm	16 kg	14 kg	16 kg	1.1	7 kg	7 kg	12 kg	0.9	No known safe limit for repetitive lifting			
		Cell A				Cell B							
Below Shoulder to Knuckle Ht	132 cm to > 81 cm	32 kg	19 kg	18 kg	1.8	16 kg	10 kg	17 kg	1.8	9 kg	8 kg	9 kg	1.1
		Cell C				Cell D				Cell E			
Knuckle Ht to Middle Shin Ht	81 cm to > 30 cm	18 kg	18 kg	23 kg	1.0	14 kg	14 kg	18 kg	1.5	7 kg	7 kg	11 kg	0.8
		Cell F				Cell G				Cell H			
Middle Shin to Floor	30 cm and lower	14 kg	14 kg	19 kg	0.9	No known safe limit for repetitive lifting				No known safe limit for repetitive lifting			
		Cell I											

Intermediate Frequency

> 2 h/day and < 30 lifts/h

Zone	Close	Middle	Far
High	14	5	--
Chest	27	14	7
Low	16	11	5
Floor	9	--	--

Higher Frequency

> 2 h/day and <360 lifts/h

Zone	Close	Middle	Far
High	11	--	--
Chest	14	9	5
Low	9	7	2
Floor	--	--	--

Other Factors

TLV Always Exceeded When

- Lifting frequency more than 360 lifts per hour
- Lifting tasks performed for longer than eight hours per day
- Lifting or placing loads in postures of trunk twisting more than 30 degrees

Professional Judgment

Perhaps Lower Limit If

- One-handed lifting
- Forward flexed trunk postures beyond 30°
- Constrained overhead posture
- High heat and humidity
- Lifting unstable objects
- Trunk postures in which the normal curve in the low back is not maintained

Hand-Arm Vibration

1986

Edited Text in 1992

Under Study

Instrumentation

Analogous to Sound Pressure

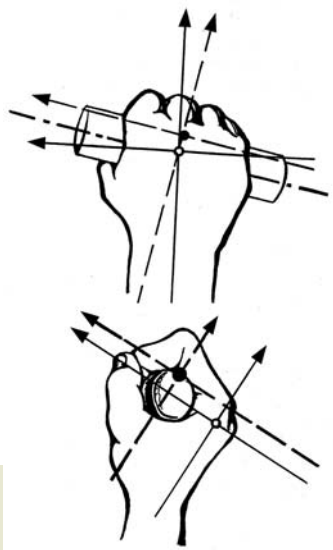
- Sum Energy Across Bands (Filtered)
- Average Energy Over Time

Accelerometer instead of Microphone

Measurement

Accelerometers: Three Axes

- Biodynamic Reference System
  - ✓z: Middle Knuckle Through Wrist
  - ✓x: Perpendicular to Palm/Back of Hand
  - ✓y: Side to Side Perpendicular to x and z
- Basicentric
  - ✓Approximation of Biodynamic
  - ✓y-axis Parallel to Handle



Total Energy

Integrate the Effective Energy Function

TLV

- Limit VWF Classification Beyond Stage 1
- Dominate Axis (Yes, but …)

- Sum All Three (Root Sum of Squares)
  - ✓Vector Addition
  - ✓Energy Addition
  - ✓More Forgiving of Placement

Average of Multiple Exposures

For each axis

TWA-Energy $(a_{eq}^2) = \Sigma\{a_i^2 * t_i\} / \Sigma\{t_i\}$

TWA-a = $a_{eq} = \{\text{TWA-Energy}\}^{1/2}$

$= \{\Sigma\{a_i^2 * t_i\} / T\}^{1/2}$

TLV Exposure Time

Acceleration	Time
4 m/s^2	4 to 8 h
6 m/s^2	2 to 4 h
8 m/s^2	1 to 2 h
12 m/s^2	< 1 h

For equivalent total energy,

$$t_{exp} = t_{crit} (a_{crit} / a_{exp})^2 = 8 \text{ h } (4 \text{ m/s}^2 / a_{exp})^2$$

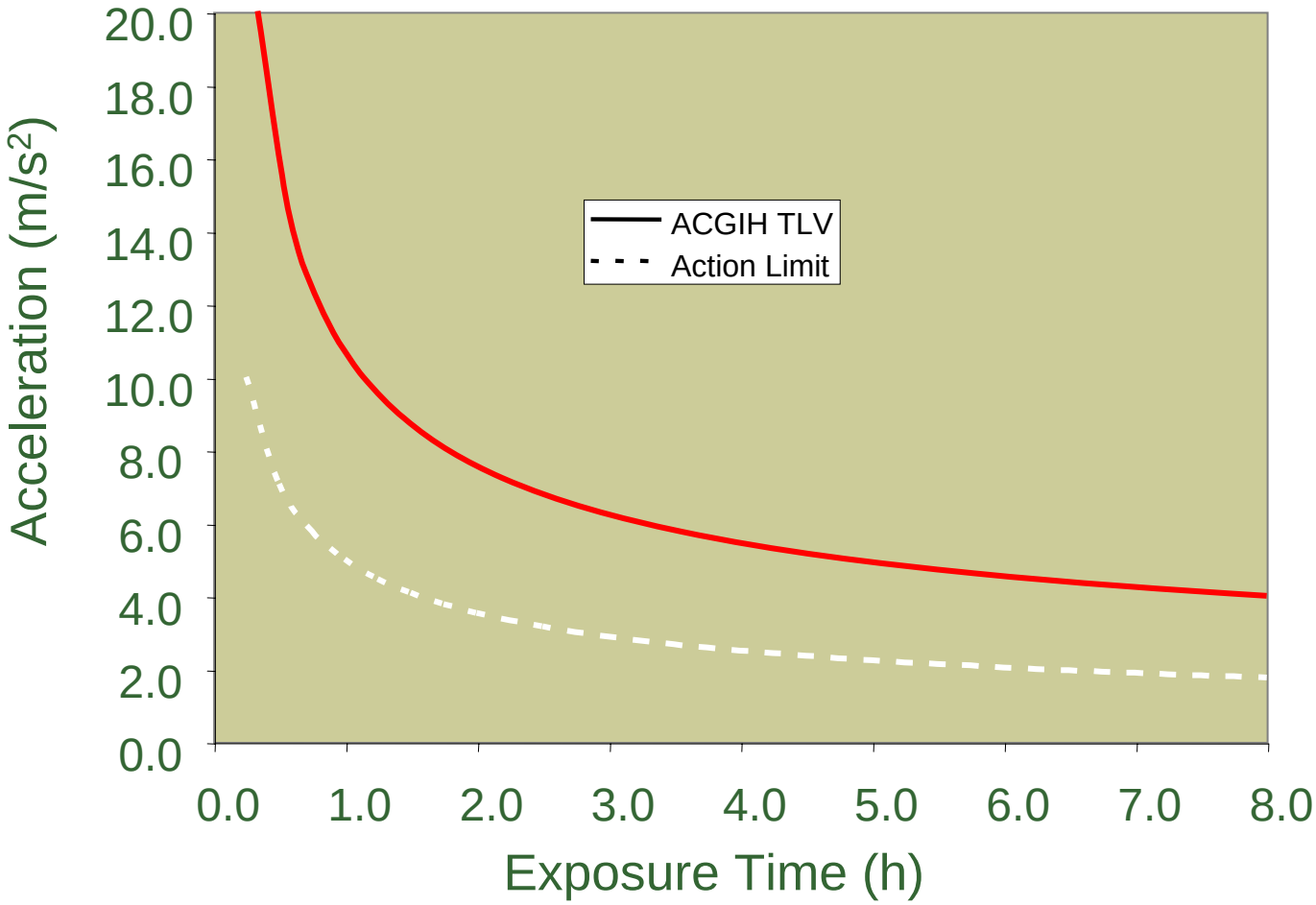
Pelmear and Leong

Lower threshold is more appropriate

For equivalent total energy,

$t_{exp} = t_{crit} (a_{crit} / a_{exp})^2 = 4 \text{ h } (2.5 \text{ m/s}^2 / a_{exp})^2$

Graphically Speaking



ISO Method

Exposure Limit

$t_{exp} = 8\ h\ (5\ m/s^2 / a_{exp})^2$

Action Limit

$t_{exp} = 8\ h\ (2.5\ m/s^2 / a_{exp})^2$

Whole Body Vibration

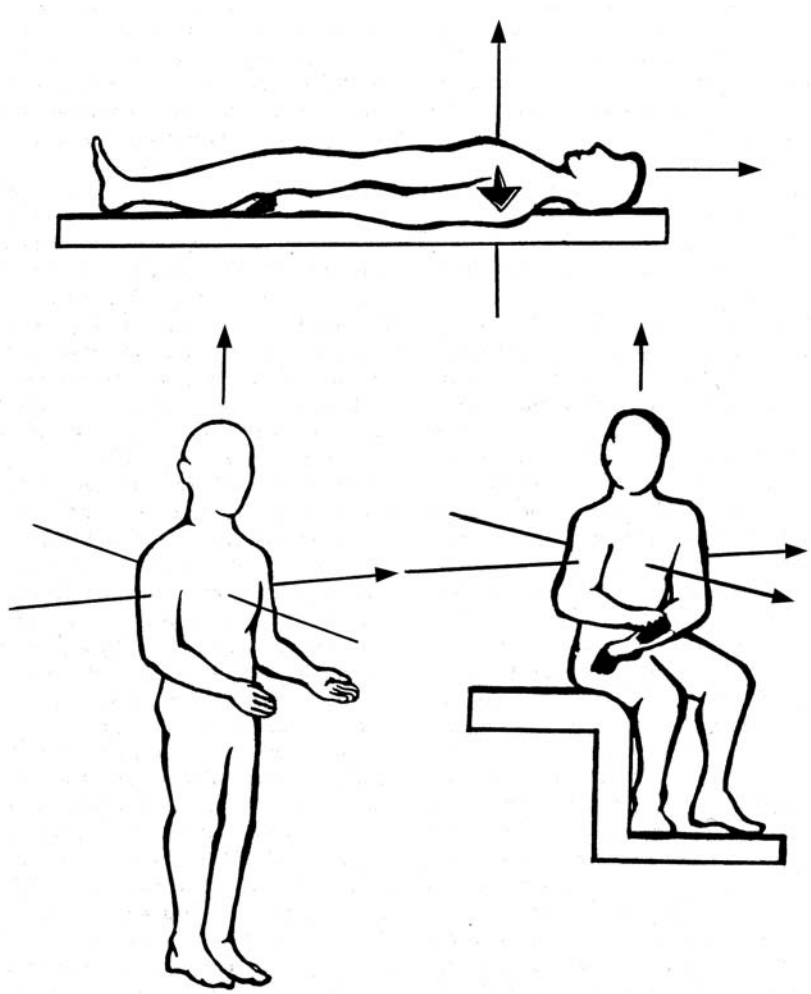
1986

Future Consideration

Measurement

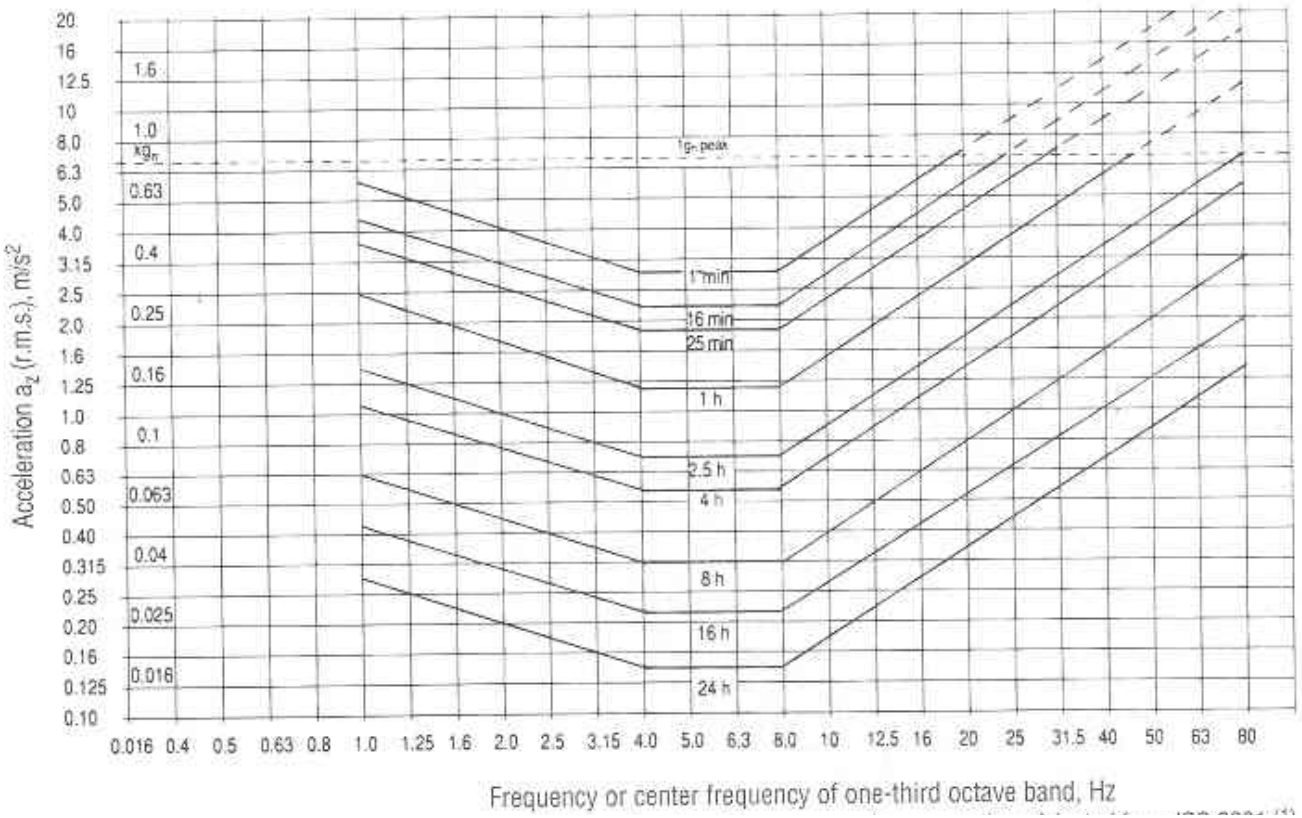
Accelerometers:
Three Axes

- Biodynamic Reference System
  - ✓z: Hips to Head
  - ✓x: Front to Back
  - ✓y: Left to Right



TLV Evaluation

Limiting 1/3 Octave Band



Total Energy

Integrate the Effective Energy Function

By Each Axis (k)

$$a_{eq\text{-}k} = [\Sigma\{(W_{i\text{-}k}\, a_{i\text{-}k})^2\}]^{1/2}$$

For Total (Sum of All Axes)

$$a_{eq} = [(1.4\, a_{eq\text{-}x})^2 + (1.4\, a_{eq\text{-}y})^2 + (a_{eq\text{-}z})^2]^{1/2}$$

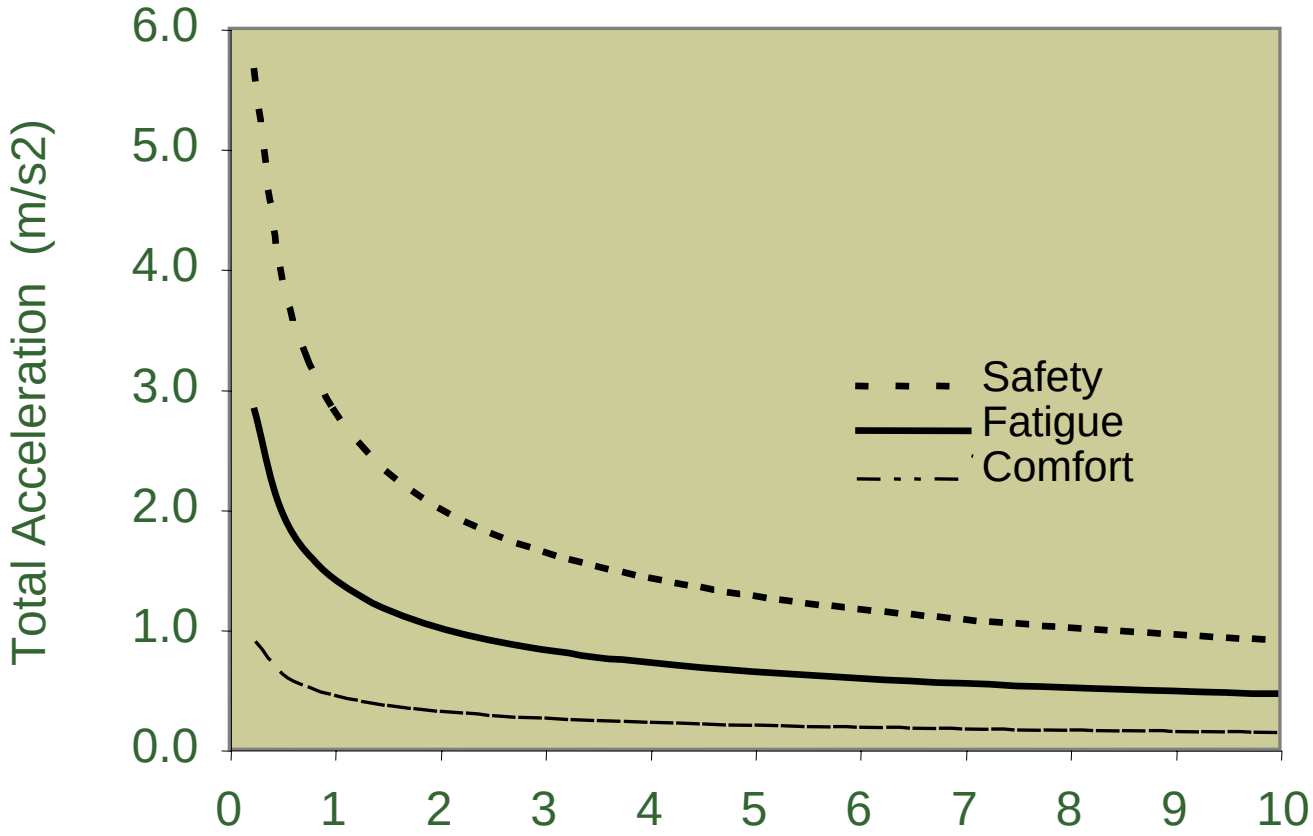
Average of Multiple Exposures

$$\text{TWA-Energy } (a_{eq}^2) = \Sigma\{a_{eq\text{-}i}^2 * t_i\} / \Sigma\{t_i\}$$

$$\text{TWA-a} = a_{eq} = \{\text{TWA-Energy}\}^{1/2}$$

$$= \{\Sigma\{a_{eq\text{-}i}^2 * t_i\} / T\}^{1/2}$$

Graphically Speaking



Exposure Time

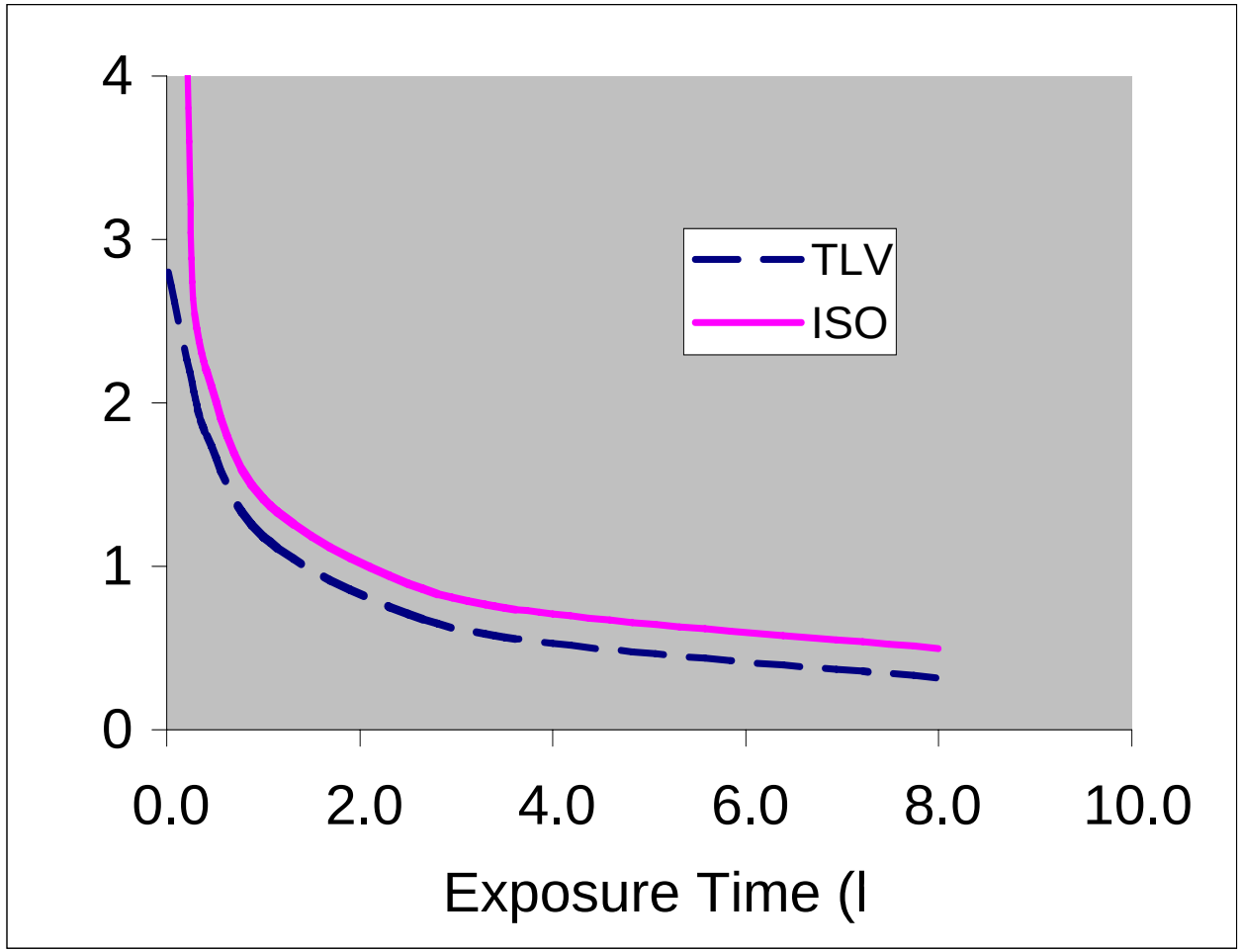
Based on recommendation from Commission of the European Communities and the ISO

For equivalent total energy,

$t_{exposure} = 8\ h\ (1.15\ m/s^2 / a_{eq})^2$

$t_{action} = 8\ h\ (0.5\ m/s^2 / a_{eq})^2$

Comparison: ISO v TLV



ISO is Higher

FYI

Movement Toward 4th Power to Handle Impacts (e.g., a^4 rather than a^2 for summing and without time-weighted average).

Called Vibration Dose Value (VDV)

$$VDV = [\Sigma\{a_{eq\text{-}i}^{4} * t_i\}]^{1/4} \ [m/s^{1.75}]$$

VDV Limits

Exposure Limit: 21 $m/s^{1.75}$

Action Limit: 9.1 $m/s^{1.75}$

Generally more protective at exposure times less than 8 hours.

Thank You

Questions?